

**REMARKS**

**Introduction**

Claims 1-24 are pending in this application. Claims 1 and 13-14 have been amended. The amendments made are fully supported by the specification as filed. No new matter has been introduced.

**Claims Rejected Under 35 U.S.C § 103(a)**

Claims 1-7, 9 and 12 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Bernstein et al., US Patent No. 6,452,251 B1 (hereinafter Bernstein) in view of Zhang et al., US Patent No. 6,420,740 B1 (hereinafter Zhang), in further view of Wang et al., US Patent No. 6,462,417 B1 (hereinafter Wang). Applicants have amended independent claim 1 in order to overcome the rejection cited by the Examiner. Applicants respectfully submit that the pending claims, as amended, are patentable over the prior art.

Newly amended independent claim 1 discloses or suggests a semiconductor device that includes an insulation film formed on a substrate, a buried interconnect formed in the insulation film and a barrier metal film formed between the insulation film and the buried interconnect. Furthermore, the barrier metal film is formed of a lamination film of a metal compound film, a fusion layer and a metal film which does not lose its conductivity when being oxidized. The fusion layer is present in between the metal compound film and the metal film and the fusion layer is obtained through fusion of the metal compound film and the metal film with each other.

The Examiner admits that Bernstein does not disclose or suggest the features of claim 1 of “a metal film which does not lose its conductivity when being oxidized” and “a fusion layer obtained through fusion of the metal compound film and the metal film with each other is present

in the vicinity of an interface between the metal compound film and the metal film," but relies on Zhang and Wang in an attempt to obviate these deficiencies of Bernstein.

Zhang discloses an  $\text{IrO}_2$  metal film which remains conductive when oxidized. In contrast, the current invention discloses a semiconductor device which includes a fusion layer that is formed in between the metal compound film and the metal film so as to extend from the interface. The fusion layer is an intermediate composition of the metal compound film and the metal film. Thus, adhesion between the metal compound film (metal oxide film) and the metal film, via the use of a fusion layer, is excellent. As a result, a highly reliable semiconductor device including a multi-layer interconnect with a low resistance and excellent adhesion can be achieved (see specification, Page 5, lines 9-15).

Wang discloses the stacking of an alloy barrier layer 226, an adhesion layer 227 and a seed layer 228 used in the formation of vias and channels or interconnects. The alloy barrier layer 226 is positioned between the adhesion layer 227 and the seed layer 228. The various layers are stacked upon each other in order to yield conductive surfaces that allegedly have good adhesion to the insulating layer and conducting layer in the formation of an interconnect. Furthermore, the various stacked layers act as a diffusion barrier in the formation of conductive vias and channels or interconnects. Although the alloy barrier layer 226 is positioned between the adhesion layer 227 and the seed layer 228, the alloy barrier layer 226 is not a fusion layer (as disclosed in the present invention). The fusion layer of the current invention is obtained through the fusion of a metal film with a metal compound film and is positioned between the insulating layer and the interconnect. However, the alloy barrier layer 226 ( $\text{CuTi}$  layer, see Fig. 3), relied upon by the Examiner as the fusion layer in the present invention, is a stacked layer positioned

between a seed layer 228 (Cu layer) and an adhesion layer 227 (TiN layer) utilized in the formation of interconnects.

In contrast, the semiconductor device as recited by the pending claims includes at least a barrier metal film that is formed of a metal compound film, a fusion layer and a metal film, which does not lose its conductivity when being oxidized. Furthermore, the fusion layer is positioned in between the metal compound film and the metal film; and the fusion layer is obtained through the fusion of the metal compound film and the metal film with each other so as to extend from the interface. The metal compound film, the fusion layer and the metal film all are part of the barrier metal film which is positioned between the insulating film and the interconnect. The fusion layer is an intermediate composition that is formed from and positioned between the metal compound film and metal film resulting in excellent adhesion between the metal compound film and the metal film. As a result, a highly reliable semiconductor device including a multi-layer interconnect with a low resistance and excellent adhesion can be achieved (see Page 5, lines 9-15 of the specification).

Therefore, for the reasons stated above, the combination of Bernstein, in view of Zhang, in further view of Wang fails to disclose each and every element of the rejected claim. Under Federal Circuit guidelines, a dependent claim is non-obvious if the independent claim upon which it depends is allowable because all the limitations of the independent claim are contained in the dependent claims, *Hartness International Inc. v. Simplimatic Engineering Co.*, 819 F.2d at 1100, 1108 (Fed. Cir. 1987). Accordingly, as claims 2-7, 9 and 12 are patentable for the reasons set forth above, it is respectfully submitted that all claims dependent thereon are also patentable. In addition, it is respectfully submitted that the dependent claims are patentable based on their own merits by adding novel and non-obvious features to the combination.

Claims 13, 16, 18-19 and 24 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Bernstein in view of Zhang. Applicants have amended independent claim 13 in order to overcome the rejection cited by the Examiner. Applicants respectfully submit that the pending claims, as amended, are patentable over the prior art.

The Examiner admits that Bernstein does not disclose or suggest the features of claim 13 of “a metal film which does not lose its conductivity when being oxidized,” but relies on Zhang in an attempt to obviate this deficiency of Bernstein. Furthermore, under the rejection of independent claim 1, the Examiner admitted that the subject matter regarding “a fusion layer obtained through fusion of the metal compound film and the metal film with each other is present in the vicinity of an interface between the metal compound film and the metal film” is not disclosed in Bernstein.

Amended independent claim 13 recites a method for fabricating a semiconductor device, including the steps of forming a recess portion in an insulation film provided on a substrate, forming a barrier metal film so that the barrier metal film covers a surface of the recess portion, and forming a buried interconnect on the barrier metal film so that the recess portion is filled. Furthermore, the step of forming the barrier metal film includes the step of forming a metal compound film of the surface of the recess portion and then forming on the metal compound film by physical vapor deposition a metal film which does not lose its conductivity when being oxidized, so that a fusion layer is obtained between the metal compound film and the metal film.

Zhang discloses an  $\text{IrO}_2$  metal film which remains conductive when oxidized. In contrast, the current invention discloses a method of forming a semiconductor device which at least includes a fusion layer that is formed in between the metal compound film and the metal film. The fusion layer is an intermediate composition of the metal compound film and the metal

film. Thus, adhesion between the metal compound film (metal oxide film) and the metal film, via the use of a fusion layer, is excellent. As a result, a method of forming a highly reliable semiconductor device including a multi-layer interconnect with a low resistance and excellent adhesion is disclosed (see specification, Page 5, lines 9-15).

Therefore, for the reasons stated above, the combination of Bernstein, in view of Zhang fails to disclose each and every element of the rejected claim. Under Federal Circuit guidelines, a dependent claim is non-obvious if the independent claim upon which it depends is allowable because all the limitations of the independent claim are contained in the dependent claims, *Hartness International Inc. v. Simplimatic Engineering Co.*, 819 F.2d at 1100, 1108 (Fed. Cir. 1987). Accordingly, as claims 16, 18-19 and 24 are patentable for the reasons set forth above, it is respectfully submitted that all claims dependent thereon are also patentable. In addition, it is respectfully submitted that the dependent claims are patentable based on their own merits by adding novel and non-obvious features to the combination.

Claims 14-15, 17 and 21 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Bernstein in view of Zhang as applied to claim 13 above, and further in view of Wang. Applicants have amended independent claim 13 in order to overcome the rejection cited by the Examiner. Applicants respectfully traverse this rejection for at least the following reasons.

The Examiner admits that Bernstein does not disclose or suggest the features of claim 13 of “a metal film which does not lose its conductivity when being oxidized,” but relies on Zhang and Wang in an attempt to obviate this deficiencies of Bernstein. Furthermore, under the rejection of independent claim 1, the Examiner admitted that “a fusion layer obtained through

fusion of the metal compound film and the metal film with each other is present in the vicinity of an interface between the metal compound film and the metal film” is not disclosed in Bernstein.

As noted above, amended independent claim 13 discloses or suggests a method for fabricating a semiconductor device, including the steps of forming a recess portion in an insulation film provided on a substrate, forming a barrier metal film so that the barrier metal film covers a surface of the recess portion, and forming a buried interconnect on the barrier metal film so that the recess portion is filled. Furthermore, the step of forming the barrier metal film includes the step of forming a metal compound film of the surface of the recess portion and then forming on the metal compound film by physical vapor deposition a metal film which does not lose its conductivity when being oxidized, so that a fusion layer is obtained between the metal compound film and the metal film.

Zhang discloses an IrO<sub>2</sub> metal film which remains conductive when oxidized, which has adhesion to a substrate. In contrast, the current invention discloses a method of forming a semiconductor device which at least includes a fusion layer that is formed in between the metal compound film and the metal film. The fusion layer is an intermediate composition of the metal compound film and the metal film. Thus, adhesion between the metal compound film (metal oxide film) and the metal film, via the use of a fusion layer, is excellent. As a result, a method of forming a highly reliable semiconductor device including a multi-layer interconnect with a low resistance and excellent adhesion is disclosed (see specification, Page 5, lines 9-15).

Wang discloses the stacking of an alloy barrier layer 226, an adhesion layer 227 and a seed layer 228 used in the formation of vias and channels or interconnects. The alloy barrier layer 226 is positioned between the adhesion layer 227 and the seed layer 228. The various layers are stacked upon each other in order to yield conductive surfaces that have good adhesion

to the insulating layer and conducting layer in the formation of an interconnect. Furthermore, the various stacked layers act as a diffusion barrier in the formation of conductive vias and channels or interconnects. Although the alloy barrier layer 226 is positioned between the adhesion layer 227 and the seed layer 228, the alloy barrier layer 226 is not a fusion layer (as disclosed in the present invention). The fusion layer of the current invention is obtained through the fusion of a metal film with a metal compound film and is positioned between the insulating layer and the interconnect. However, the alloy barrier layer 226 (CuTi layer, see Fig. 3), relied upon by the Examiner as the fusion layer in the present invention, is a stacked layer positioned between a seed layer 228 (Cu layer) and an adhesion layer 227 (TiN layer) resulting in a strong coherent bond or good adhesion in the formation of interconnects.

In contrast, the current invention discloses a method of forming a semiconductor device which at least includes a barrier metal film that is formed of a metal compound film, a fusion layer and a metal film, which does not lose its conductivity when being oxidized. Furthermore, the fusion layer is positioned in between the metal compound film and the metal film; and the fusion layer is obtained through the fusion of the metal compound film and the metal film with each other so as to extend from the interface. The metal compound film, the fusion layer and the metal film all are part of the barrier metal film which is positioned between the insulating film and the interconnect. The fusion layer is an intermediate composition that is formed from and positioned between the metal compound film and metal film resulting in excellent adhesion between the metal compound film and the metal film. As a result, a highly reliable semiconductor device including a multi-layer interconnect with a low resistance and excellent adhesion can be achieved (see Page 5, lines 9-15 of the specification).

Therefore, for the reasons stated above, the combination of Bernstein, in view of Zhang and further in view of Wang fails to disclose each and every element of the invention. Under Federal Circuit guidelines, a dependent claim is non-obvious if the independent claim upon which it depends is allowable because all the limitations of the independent claim are contained in the dependent claims, *Hartness International Inc. v. Simplimatic Engineering Co.*, 819 F.2d at 1100, 1108 (Fed. Cir. 1987). Accordingly, as claims 14-15, 17 and 21 are patentable for the reasons set forth above, it is respectfully submitted that all claims dependent thereon are also patentable. In addition, it is respectfully submitted that the dependent claims are patentable based on their own merits by adding novel and non-obvious features to the combination.

Claim 8 has been rejected under 35 U.S.C. §103(a) as being unpatentable over Bernstein in view of Zhang further in view of Wang as applied to claim 1 above, in still further in view of Asahina et al., US Patent No. 6,144,097 (hereinafter Asahina). Applicants have amended independent claim 1 in order to overcome the rejection cited by the Examiner. Applicants respectfully traverse this rejection for at least the reasons stated above regarding independent claim 1, therefore the combination of Bernstein in view of Zhang, further in view of Wang and still in further view of Asahina, fails to disclose each and every element of the invention.

Claim 20 has been rejected under 35 U.S.C. §103(a) as being unpatentable over Bernstein in view of Zhang as applied to claim 13 above, and further in view of Asahina. Applicants have amended independent claim 13 in order to overcome the rejection cited by the Examiner. Applicants respectfully traverse this rejection for at least the reasons stated above regarding independent claim 13, therefore the combination of Bernstein in view of Zhang, and further in view of Asahina, fails to disclose each and every element of the invention.

Claim 10 has been rejected under 35 U.S.C. §103(a) as being unpatentable over Bernstein in view of Zhang further in view of Wang as applied to claim 1 above, and further in view of Wang et al., US Patent No. 6,445,070 B1 (hereinafter Wang II). Applicants have amended independent claim 1 in order to overcome the rejection cited by the Examiner. Applicants respectfully traverse this rejection for at least the reasons stated above regarding independent claim 1, therefore the combination of Bernstein in view of Zhang, further in view of Wang and still in further view of Wang II, fails to disclose each and every element of the invention.

Claim 22 has been rejected under 35 U.S.C. §103(a) as being unpatentable over Bernstein in view of Zhang as applied to claim 13 above, and further in view of Wang II. Applicants have amended independent claim 13 in order to overcome the rejection cited by the Examiner. Applicants respectfully traverse this rejection for at least the reasons stated above regarding independent claim 13, therefore the combination of Bernstein in view of Zhang, and further in view of Wang II, fails to disclose each and every element of the invention.

Claim 11 has been rejected under 35 U.S.C. §103(a) as being unpatentable over Bernstein in view of Zhang further in view of Wang as applied to claim 1 above, and further in view of Terry et al., US Patent No.4,675,713 (hereinafter Terry). Applicants have amended independent claim 1 in order to overcome the rejection cited by the Examiner. Applicants respectfully traverse this rejection for at least the reasons stated above regarding independent claim 1, therefore the combination of Bernstein in view of Zhang, further in view of Wang and still in further view of Terry, fails to disclose each and every element of the invention.

Claim 23 has been rejected under 35 U.S.C. §103(a) as being unpatentable over Bernstein in view of Zhang as applied to claim 13 above, and further in view of Terry. Applicants have amended independent claim 13 in order to overcome the rejection cited by the Examiner.

Applicants respectfully traverse this rejection for at least the reasons stated above regarding independent claim 13, therefore the combination of Bernstein in view of Zhang, and further in view of Terry, fails to disclose each and every element of the invention.

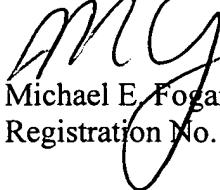
**Conclusion**

The Applicants have addressed all rejections/objection raised by the Examiner. Accordingly, it is believed that all pending claims are now in condition for allowance. Applicants therefore respectfully request an early and favorable reconsideration and allowance of this application. If there are any outstanding issues which might be resolved by an interview or an Examiner's amendment, the Examiner is invited to call Applicants' representative at the telephone number shown below.

To the extent necessary, a petition for an extension of time under 37 C.F.R. 1.136 is hereby made. Please charge any shortage in fees due in connection with the filing of this paper, including extension of time fees, to Deposit Account 500417 and please credit any excess fees to such deposit account.

Respectfully submitted,

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